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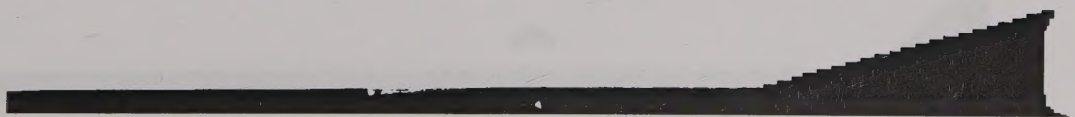

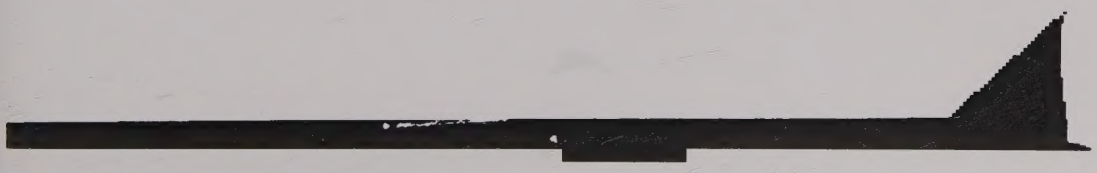

THE STRUCTURE OF WHEAT

SHOWN IN A SERIES OF

PHOTO-MICROGRAPHS,

WITH EXPLANATORY REMARKS.

BY

ROBERT W. DUNHAM.

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CONTENTS.

			PAGE
TITLE			1
CONTENTS			2
PREFACE			3 & 4
AN EAR OF WHEAT			5
PHOTO-MICROGRAPH OF THE WHEAT STRAW AND KNOT, MAGNIFIED 12 DIAMS.			6
,, ,,	A WHEAT STRAW KNOT ... ... ,,	20 ,,	7
,, ,,	THE WHEAT FLOWER BEFORE FERTILISATION ,,	20 ,,	8
,, ,,	THE STIGMA BEFORE FERTILISATION ... ,,	65 ,,	9
,, ,,	THE FLOWER AFTER FERTILISATION... ... ,	20 ,,	10
,, ,,	THE STIGMA WITHERING AWAY ... ... ,,	20 ,,	11
,, ,,	LONGITUDINAL SECTION OF A GRAIN OF WHEAT ,,	12 ,,	12
,, ,,	THE OUTER SKIN WITH BEARD ... ... ,,	16 ,,	13
,, ,,	THE OUTER SKIN ... ... ,,	165 ,,	14
,, ,,	THE MIDDLE SKIN ... ... ,,	16 ,,	15
,, ,,	THE MIDDLE SKIN ... ... ,,	250 ,,	16
,, ,,	THE INNER SKIN ... ... ,,	16 ,,	17
,, ,,	THE INNER SKIN ... ... ,,	250 ,,	18
,, ,,	LONGITUDINAL SECTION OF OUTER AND MIDDLE SKINS ... ... ,,	290 ,,	19
,, ,,	CROSS-SECTION OF SKINS WITH PORTION OF ENDOSPERM ... ... ,,	333 ,,	20
,, ,,	,, ,, ,, ,, ,,	330 ,,	21
,, ,,	OBLIQUE CROSS-SECTION FROM BEARD END TO CENTRE ... ... ,,	20 ,,	22
,, ,,	OBLIQUE CROSS-SECTION SHOWING PLACENTA AND GERM ... ... ,,	16 ,,	23
,, ,,	LONGITUDINAL SECTION OF GERM ... ... ,,	21 ,,	24
,, ,,	CROSS-SECTION THROUGH CENTRE OF GERM ,,	35 ,,	25
,, ,,	,, ,, END OF GERM ... ,,	50 ,,	26

THE STRUCTURE OF WHEAT.

THE photographic reproductions of the different organs of the wheat plant which I have now the honour of submitting to the world owe their existence to the process of photo-micrography. With the details of that delicate process this work is not concerned, but as a tree is judged by its fruit, so may any distinctive method of scientific research be fairly estimated by its broad results. And photo-micrography has no reason to shrink from this test. The wonders of the microscope have passed into a household expression, but until the microscopist learned to make use of the photographer's camera those wonders were a sealed book to the many. It is true that from the earliest days of microscopic research some of the results achieved have been committed to paper, but all those drawings or sketches, being more or less the work of memory, were necessarily faulty or imperfect. It is only by photo-micrography—that is to say, by the joining of the microscope and camera in one instrument—that the science of microscopy can be said to have reached its highest expression. Eyes adapted for microscopic research are given but to few, and, under the best conditions, work with high powers can only be pursued with slow and fitful steps. The student, however, who calls to his aid photo-micrography is provided with a collaborator which will register, in a form as permanent as anything may be in this world, and with absolute accuracy, all the results of his research. He obtains a photograph of the image revealed by his lenses, and this image can be reproduced in its finest details. It is obvious that such reproductions must possess a far higher value than the memory sketches which formerly were produced at the cost of painful and injurious labour. For it should never be forgotten that the strain on the eye increases in a geometric ratio to the magnitude of the diameters, and that the student who would charge his memory with a load of details revealed by a high power must of necessity subject his vision to a prolonged and therefore dangerous strain. In many cases, work extended beyond due limits would have the effect of defeating its purpose, as the details of the object under examination would become blurred and indistinct to the overtaxed organ.

The possibilities of photo-micrography are too vast for speculation. For as we increase our knowledge of the minute structures of this planet, and as we store up the knowledge so obtained in a permanent and accessible form, what secrets of nature's

laboratory may we not hope to unlock? Of the results achieved in the small field in which I have elected to labour I have some diffidence in speaking, but I cannot but be conscious that my knowledge of the structure of the wheat plant has been very considerably enlarged. I have learnt that the five skins with which orthodox teachers have endowed the berry are really not five but three. That is to say, there are only three distinct skins, and though these divisions are capable of subdivision, yet each skin remains a separate organism. It is also made clear that the so-called gluten cells which cluster in a chain near the periphery of the grain are not gluten cells at all, but are chambers filled with cerealine. This cerealine is a lactic ferment, and has a most important function in the organisation of wheat, as it serves to dissolve the gluten and starch on which the infant plant must feed before it can draw its own nutriment, by its rootlets and leaves, from the earth and atmosphere. It might be said that these cerealine cells are the nurse to whose fostering care the plant is committed in its babyhood. The gluten, that fortifying element on which students of wheat have had so much to say, is clearly discernible in these photographs. It has a web-like form, and is spread out somewhat after the manner of a fishing net, to which it has a distinct resemblance. Within its folds are packed starch cells and granules. Very distinct are the functions of the placenta, which may be observed at the base of the crease. It is covered by the outer skin, and has the deepest layer of skin on its inner side, while it is itself folded within the middle or compound skin. The placenta is a very effective filter, its function being to prepare for the use of the berry the food that is sucked up from the ground through the stalk, passing through the porous nodules of the straw. A large proportion of the bodies filtered by the placenta is mineral matter, and when not digested remains in the crease. This is what is popularly called crease dirt. Some of this mineral matter may be seen in these photographs on its passage through the placenta cord, which readily recalls the umbilical cord of the human body. Another organ with an important part is the beard, of which the innermost structure is clearly revealed by this process. The plant can as little exist without water as without food, and the hairs of the beard act as channels, to relieve the plant from superfluous moisture, that would otherwise cause injurious fermentations. The outer covering of the berry is not porous, like the human skin, and, as a matter of fact, wheat perspires through its hair.

I must not conclude this brief introduction without expressing my sincerest thanks to Mr. Richard Smith, the well-known miller and inventor of Hovis bread, without whose aid this collection of photographs might never have been brought into existence. Mr. Smith has for twenty years been a diligent user of the microscope, and it was he who first called my attention to the light which that instrument must throw on the structure of wheat. His remarks so impressed me that from that time I resolved to avail myself of all the assistance which the microscope could afford. That these researches have been embodied in a permanent form is the merit of photo-micrography.

R. W. D.

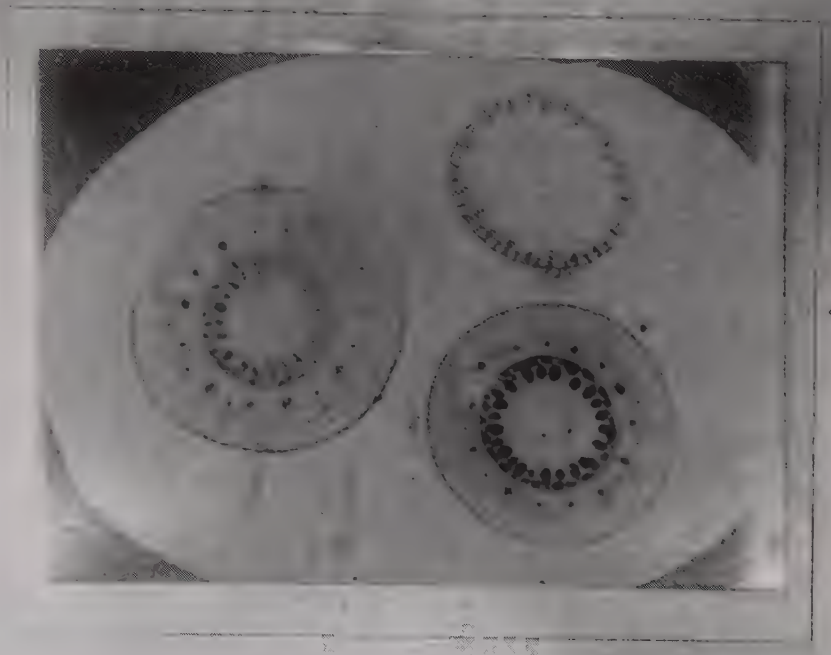
An Ear of Wheat.

Natural Size.

To man, whose daily bread is furnished by the wheat berry, there can be few scientific problems more interesting than the anatomy and morphology of this cereal. And assuredly the natural history of wheat will repay study. A grain of wheat is produced by the flower, and obviously grows till it has attained maturity, that is, till the seed is ripe. But why does not the seed continue to grow? Why does it stop growing when ripe? Why is there what may be called a resting stage? These are scientific questions; the resting stage really depends upon the condition of the ferments contained in the grain of wheat. The wheat plant, as we know it, is never found in a wild state. It does not appear conceivable that this cereal should thrive untended by man, because germination, fertilisation and maturation are delicate operations that can only be properly carried into effect at certain seasons and in certain temperatures. To ripen properly, wheat must be sown not hap-hazard but at a chosen time, and therefore the cultivation of wheat necessarily demands not the automatic machinery of bird, or insect, or wind fertilisation, but the fostering care of man. As a matter of fact wheat is self-fertilising, the pistilate and staminate portions of the flower being close together and contained in a case by which they are completely protected from contact with the pollen of any other flower. Wheat is pre-eminently the servant of civilised man, and might be termed, without exaggeration, "civilisation's barometer." Beyond question the success of the wheat culture of any country will be in proportion to its degree of civilisation. The process of germination is not exacting as regards temperature, 40 degs. Fahr. being sufficient. When germination starts, the germ, which is prepared in the ear of the parent plant, feeds on the remainder of the interior of the berry until the rootlets protrude, and are sufficiently developed to supply the growing germ or "life" with the necessary nourishment from the earth. An ear of wheat is formed by an assemblage of a number of spikelets, and is supported by a circular plate which forms the straw. The length of the ear and the number of spikelets vary according to the kind of wheat grown. Taking a solitary spikelet it will be found that it consists of a number of florets, generally from two to six, gathered together so as to form one envelope composed of two scale husks, called shields or protecting glumes. The spikelet is shaped like a fan, and presents its broadest face to the extension of the upper straw that acts as its stem. When the spikelet is examined it will be noticed that the two outer shields or glumes remain empty, and that each of the lower florets contains a grain. The object of the farmer, in order to obtain a good yield of wheat, is to get all the florets filled with berries, but unless the critical period, that of fertilisation, has been fortunately passed through, the harvest cannot be a good one.

A Photo-Micrograph of the Wheat Straw.—Section through the Straw and Knot of the Straw.

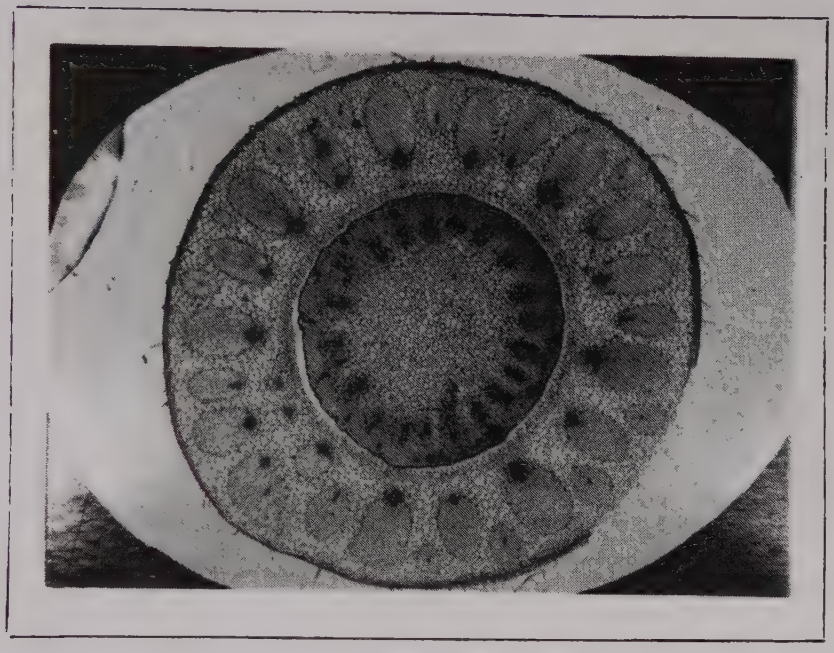
Magnified 12 diameters.



The straw does not form one single tube from the wheat ear to the root, but generally consists of four tubes separated the one from the other by four knots, each knot being situated at the point where two tubes are joined together. Above are three views—one is a section of the straw, while each of the other two shows a section through the knot itself. The straw of an average crop of wheat of 30 bushels will draw the following constituents from the soil:—18 lbs. potash, 2 lbs. of soda, 9 lbs. of lime, 4 lbs. of magnesia, 8 lbs. of phosphoric acid, and 110 lbs. of silica

A Photo-Micrograph of the Wheat Straw—Section through the Knot.

Magnified 20 diameters.



The above represents a section through the knot of the straw as shown on the preceding page, but magnified 20 diameters, and it will be noticed that the knot is solid. It is formed in such a manner that it makes an apex in the lower straw, into which the upper straw is tongued so as to give greater strength.

A Photo-Micrograph of the Wheat Flower before Fertilisation.

Magnified 20 diameters.

The organs of the flower are most adequately protected against all exterior disturbances. The flower which is represented above is enclosed in two envelopes, the outside glume being concave and furnished at its upper end with a spike. The other, or interior glume, exactly fits into the first, and contains the organs of reproduction, enclosed in two folds or curtains that spring from the edges of this glume. Finally, as a precaution, the edge of the second glume is provided with hairs all along its ridge, to prevent the entry of foreign bodies from outside. In each flower is an ovary surmounted by a stigma shaped something like a tree with two branches. The photo-micrograph above gives an excellent idea of the organs of reproduction in wheat previous to fertilisation. The anthers are green, and present their broadest surface to the stigma which they surround.

A Photo-Micrograph of a Portion of the Stigma.

Magnified 65 diameters.

The photo-micrograph above represents a portion of the feathery stigma of the wheat flower magnified 65 diameters. It will be noticed that the stigma is provided with smaller branches, and that to these latter alone are fixed fine tubes, which are intended to receive the pollen or fertilising dust that falls from the anthers when they open at the side. This happens when they are perfectly mature and there is sufficient warmth. The temperature must not be below 70 degs. Fahr.

A Photo-Micrograph of the Stigma and Ovary after Fertilisation.

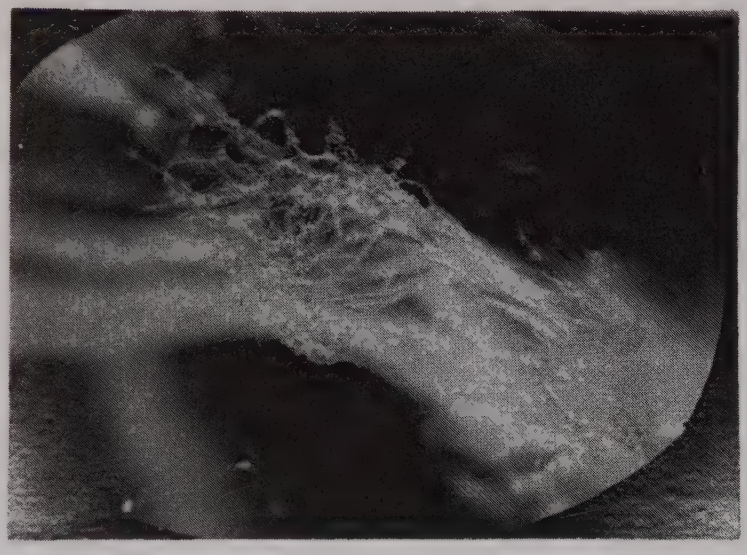
Magnified 20 diameters.

When the organs of the floret have arrived at maturity it is very easy to follow the phenomena of fertilisation by the following process:—A flower is detached from the spikelet, and an incision made in the outer glume from the top to the bottom, so as to lay bare the flower. Should the organs of the flower be perfectly mature a ray of sunlight, or the heat of the breath, will suffice to instantly bring about fertilisation, which is effected by the anthers opening at the side and being at the same time seized with an undulating movement; the pollen particles are split and settle on the very fine tubes with which the stigmas are furnished. These tubes act as suction ducts, and absorb the fovilla out of the pollen; they convey it to the small branches, then these convey it to the larger branches, and lastly to the ovary. The photo-micrograph above represents the stigma and ovary after fertilisation, that portion of the stigma which has a downy appearance being out of focus.

When the anthers let loose their pollen the three stamen filaments extend with great rapidity, and the stamens are thrown out of the flower as organs for which there is no longer any use; then they quickly dry up and soon drop off.

A Photo-Micrograph of the Stigma of the Wheat Flower Withering after Fertilisation.

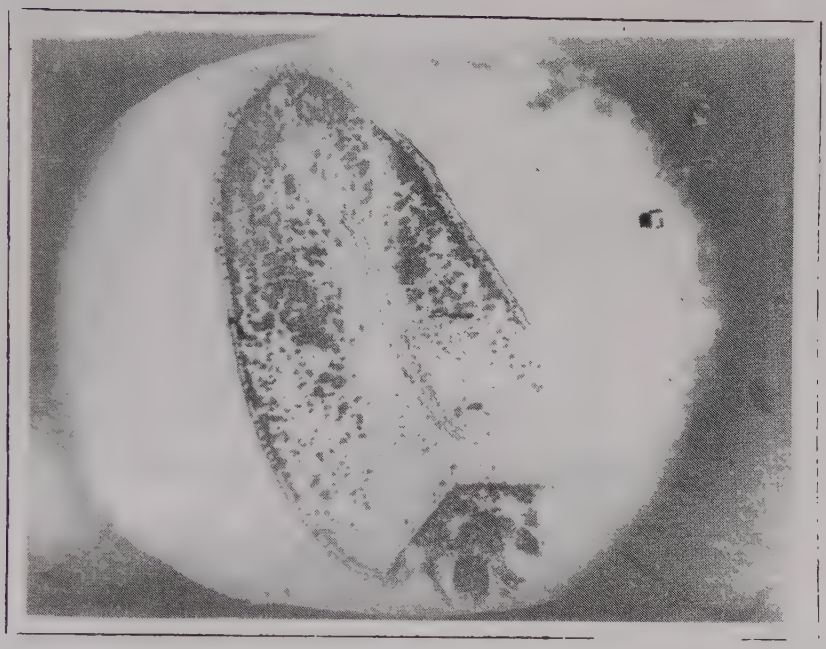
Magnified 20 diameters.



If, at the time of the wheat harvest, a fertile floret be examined, it will be noticed that no trace remains of the two minute glands which were palpable enough in the flower, and that the three stamens have entirely disappeared, while the lovely style and stigma are only represented by a whitish silky trace on the top of the grain. It will thus be seen that the wheat grain is obviously the ripened ovary, and therefore the *fruit* of the wheat plant, which botanists term a caryopsis. The photo-micrograph above represents the stigma, magnified 20 diameters, withering away after fertilisation has taken place.

A Photo-Micrograph of a Longitudinal Section of a Grain of Wheat, cut horizontally near the Crease.

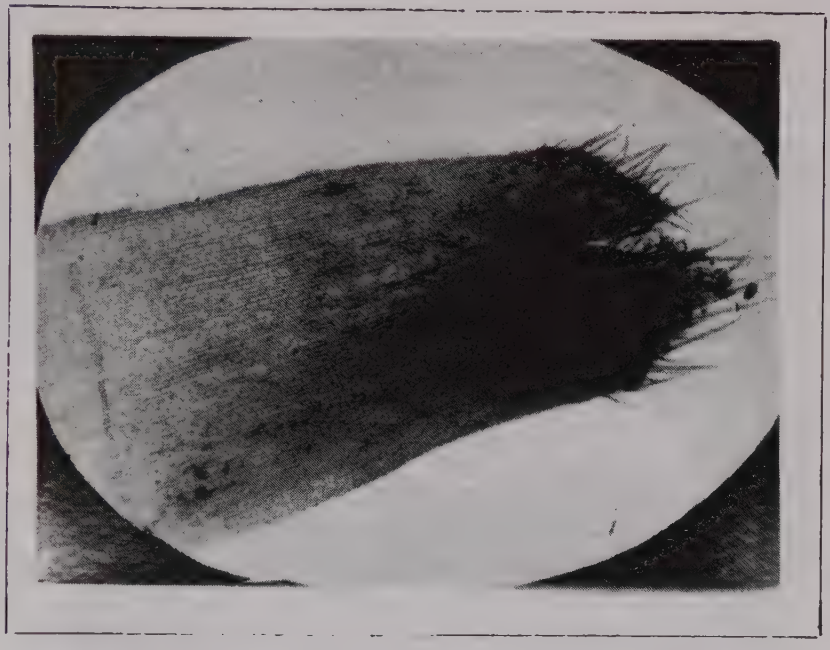
Magnified 12 diameters.



The above gives a view of the structure of a grain of wheat, obtained by cutting a slice near the crease in the wheat, and having it magnified 12 diameters and photographed. The slice was so thin that a portion at the bottom right hand corner broke away, and when it was being mounted for the microscope a certain portion of the starch fell out, leaving only the gluten webbing.

A Photo-Micrograph of a Portion of the External Skin of Wheat, with Beard.

Magnified 16 diameters.

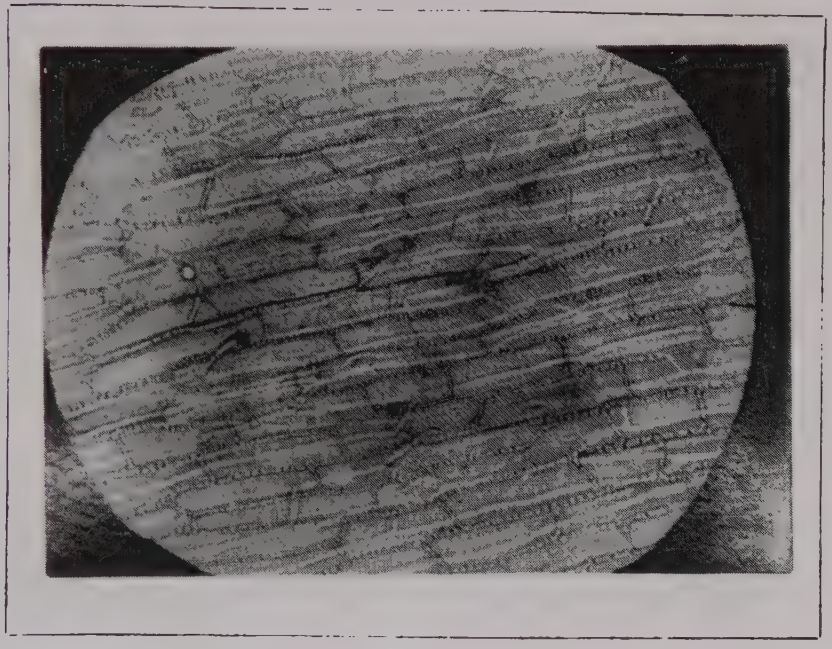


A grain of wheat is generally supposed to possess five skins, named in botany epidermis, epicarp, endocarp, episperm and embryous membrane, whereas in reality there are but three skins, which, however, are capable of artificial subdivision. The photo-micrograph on this page is taken from a portion of the external skin of the wheat, with the beard, magnified 16 diameters in the process of reproduction.

It will be noticed that the hairs of the beard are hollow. These hollow hairs are, in effect, conduits, of which it is the function to draw off the superfluous moisture that would otherwise cause prejudicial fermentation. On the other hand, it is the proper function of this moisture to convey to the kernel its mineral and gaseous food. Another duty of the beard is connected with the earliest life of the plant, for when the seed is first sown these hair ducts suck up the moisture necessary for the process of germination.

A Photo-Micrograph of a Portion of the External Skin of Wheat,

As shown on page 13, but magnified 165 diameters.

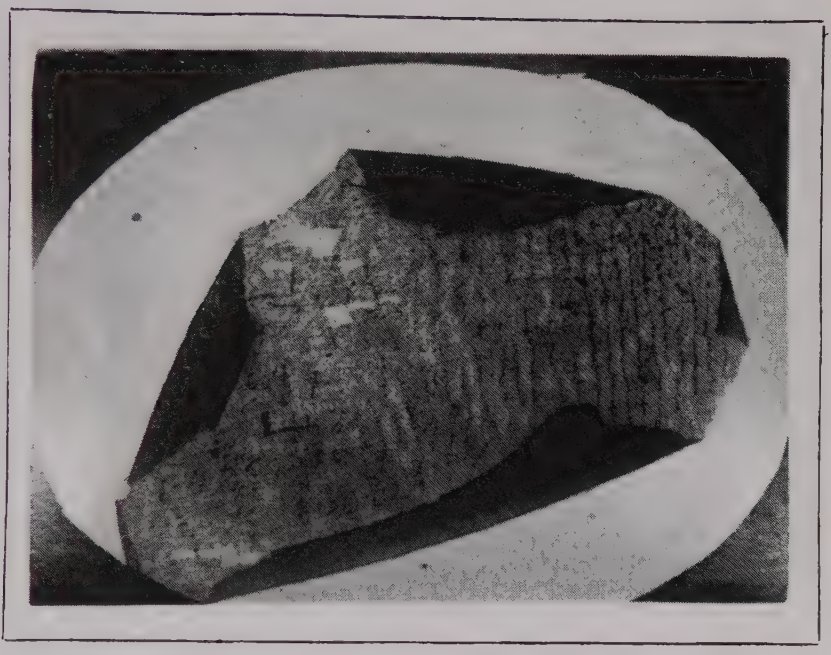


Above we have a portion of the outer skin of a grain of wheat, magnified 165 diameters, so as to show the structure in a more defined manner.

The white lines showing through the face of the skin represent that portion of the structure which, by reason of its thickness, was out of focus when the photo-micrograph was taken. The existence of these lines is, however, a conclusive proof that throughout its thickness this skin is but one structure.

A Photo-Micrograph of a Portion of the Middle or Compound Skin.

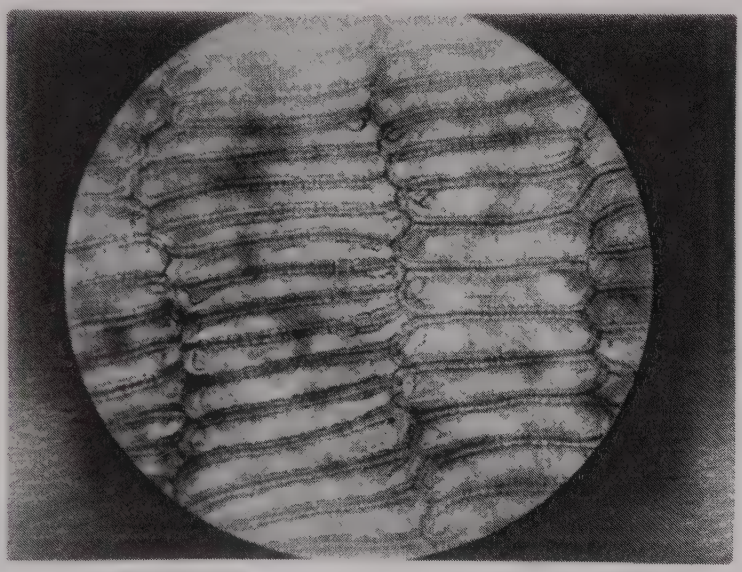
Magnified 16 diameters.



As will be seen from the above, the middle skin is a compound skin. This is plainly proved from the fact of small fragments having been detached from the top left-hand corner and the bottom left-hand corner, exposing an essentially identical structure below. The cells are so arranged as to lay in the top and bottom structure across one another, in order to give extra strength and protection in case any injury should happen to the outer skin of the grain of wheat.

A Photo-Micrograph of a Portion of the Middle or Compound Skin,

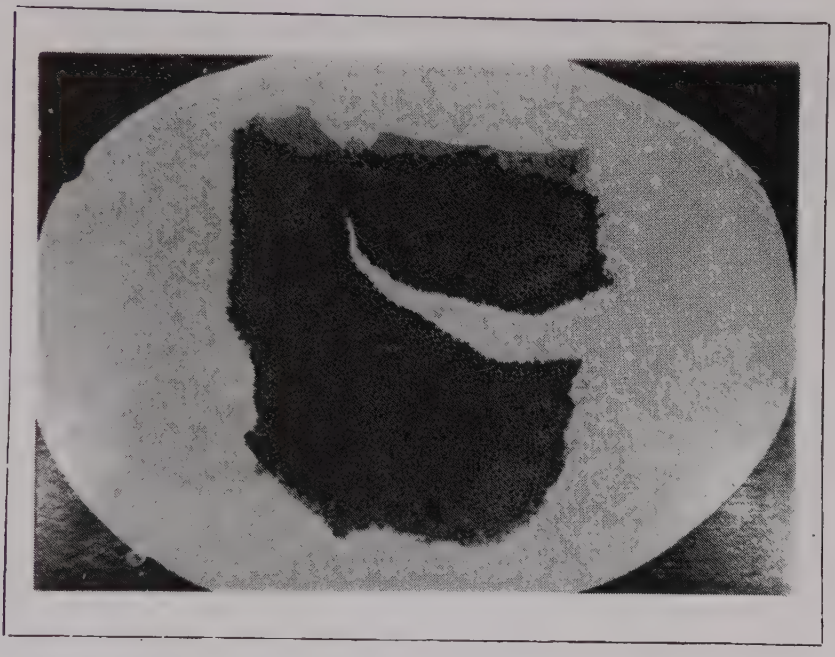
As shown on page 15, but magnified 250 diameters.



The above is a portion of the middle or compound skin of a grain of wheat, magnified 250 diameters. The small cells forming the compound skin contain two colouring matters, the one being pale yellow and the other orange yellow in hue. The predominance of either colour is chiefly due to the nature of the soil on which the wheat is grown. This is the origin of the varieties known in commerce as White, Yellow or Red Wheats.

A Photo-Micrograph of a Portion of the Inner Skin or Coating of Cerealine Cells.

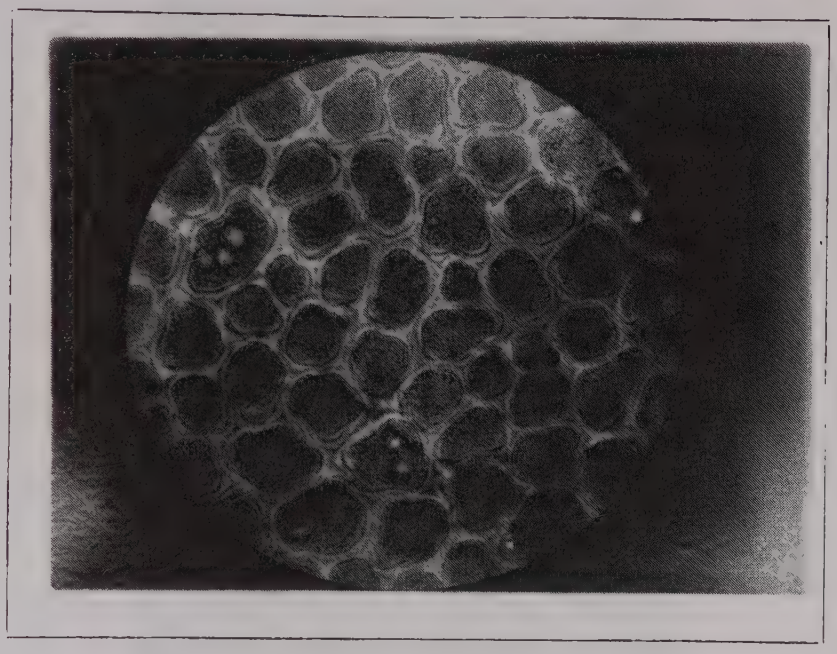
Magnified 16 diameters.



The inner skin of the wheat consists of irregular cells, which in the reproduction above are well defined being magnified 16 diameters. This skin is generally nearly as thick as the outer and middle coats together, but the thickness will vary with the ripeness of the wheat. This skin, or layer of cerealine cells, is composed of insoluble cellular tissue, phosphate of chalk and fatty phosphoric bodies, and also contains soluble cerealine, but no gluten.

A Photo-Micrograph of a Portion of the Inner Skin or Coating of Cerealine Cells,

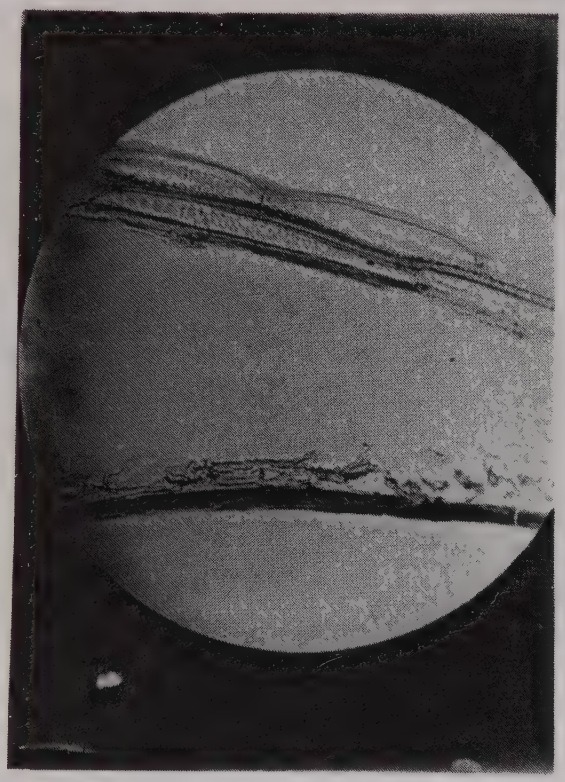
As shown on page 17, but magnified 250 diameters.



The photo-micrograph above represents a portion of the inner skin or coating of cerealine cells, magnified 250 diameters. These cells diminish in size as they come nearer to the embryo or germ, and at the beard end increase considerably in thickness. The cerealine cells contain agents capable of dissolving the plastic nutriments, or floury portion of the wheat berry, during the germination and growth of the young plant until it can supply itself with food from the earth and air.

A Photo-Micrograph of the Outer and Middle Skins.

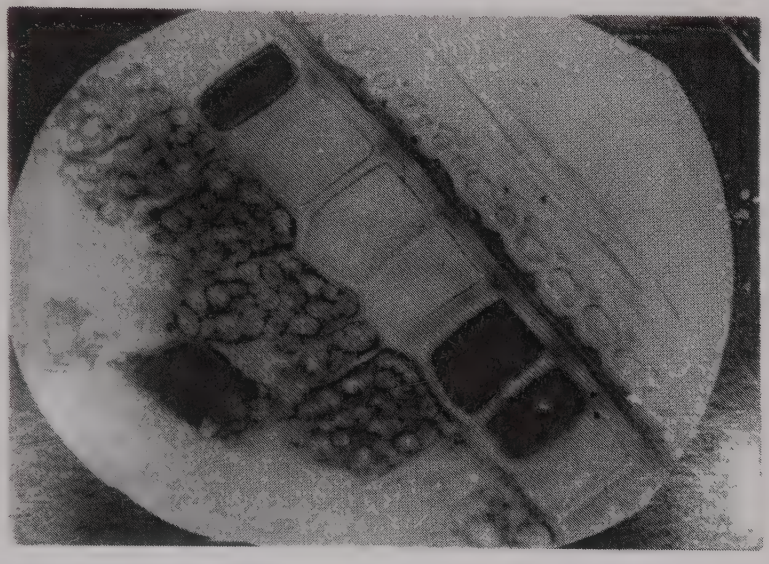
Longitudinal Section magnified 290 diameters.



The above represents a longitudinal section of the outer and middle skins of the wheat berry magnified 290 diameters. It will be noticed that the structure of the outer skin consists of two layers of cells, which differ in thickness at different points, whence it may fairly be argued that this skin is but one structure. The lower skin shown above is the compound skin, which is made up of two structures laid crosswise.

A Photo-Micrograph of a Portion of a Grain of Wheat.

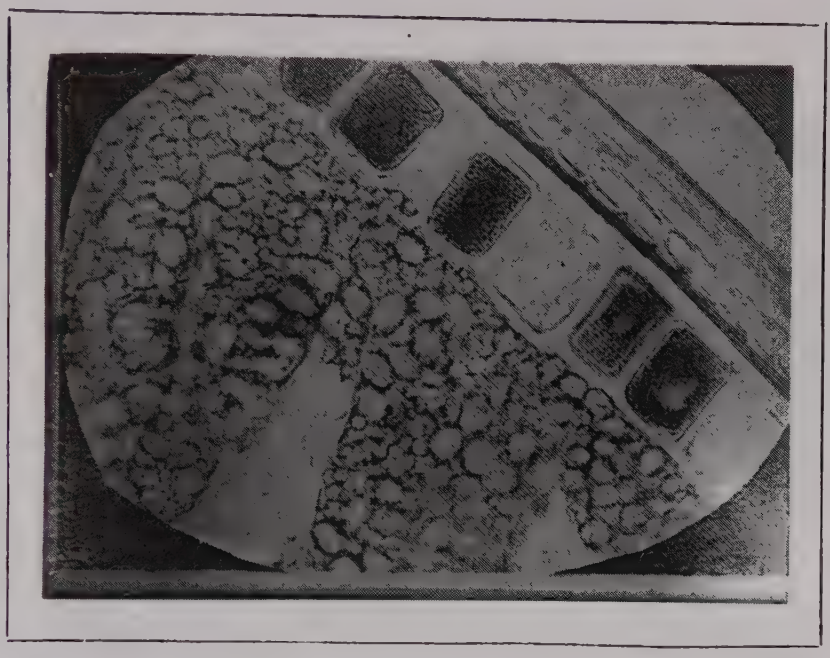
Cross-section showing three Skins and Endosperm magnified 333 diameters.



The photo-micrograph above is part of a piece of wheat cut in section, so as to show the three skins and a little of the endosperm. The section is magnified 333 diameters, and illustrates the building up of the floury elements in the growth of the wheat berry.

A Photo-Micrograph of a Portion of the Wheat Berry cut in Section, showing Skins and Endosperm.

Magnified 330 diameters.



The endosperm, or floury portion, is that portion of the wheat berry which the scientific miller has to disintegrate. It is his aim to free it from the bran, which comprises the three envelopes, and also to eliminate the germ. The endosperm consists of gluten walls and starch, and the gluten is arranged in a fine network, which extends to the centre of the berry, forming, with the starch, the inside of the wheat berry, which is very well shown above. The gluten is not distributed equally throughout the berry, the meshes of gluten being much finer in quality, and more dense near the bran than at the centre.

A Photo-Micrograph of a Portion of a Grain of Wheat. An Oblique Cross-section from the Beard End.

Magnified 20 diameters.

The above is a photo-micrograph of an oblique cross-section of a portion of a grain of wheat magnified 20 diameters, and taken from the beard end to a central point between the two ends. The position of the placenta is very well shown, and the manner in which the beard grows in relation to the skins is readily seen.

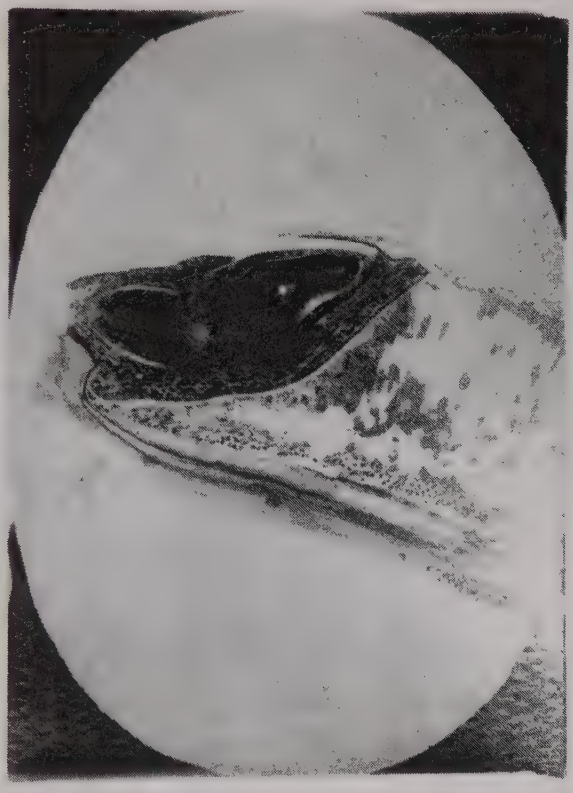
A Photo-Micrograph of a Portion of a Wheat Berry cut Obliquely through the Germ.

Magnified 16 diameters.

The above photo-micrograph is an oblique cross-section of a grain of wheat through the top of the germ, showing the position of the placenta and the germ. As the stream of food which is to be stored for the young plant, and therefore to form the endosperm, flows up the straw and reaches the top of the wheat berry, the surplus water passes away from it through the beard. It is by means of the placenta that the food is carried from the straw to the endosperm, and this, when broken up in milling, gives the flour a dark tinge. It would be useless to peel off the skins of the berry entire, if the placenta were not eliminated, because the latter, when reduced into flour, would impart a distinctly dark tinge, containing, as it does, mineral matter.

A Photo-Micrograph of a Section through the Germ, showing the Root and Plumule.

Magnified 21 diameters.



The embryo or germ of the wheat berry is composed of the root and plumule of the plant which is to grow, and these are embedded in a mass of cells full of fatty bodies. These bodies contain among their elements sulphur and phosphorus. The photo-micrograph above is a vertical longitudinal section through the germ, showing its position as regards the crease and its connection with the placenta, which, when it germinates, supplies it with the liquid food obtained when the endosperm is broken down by fermentation.

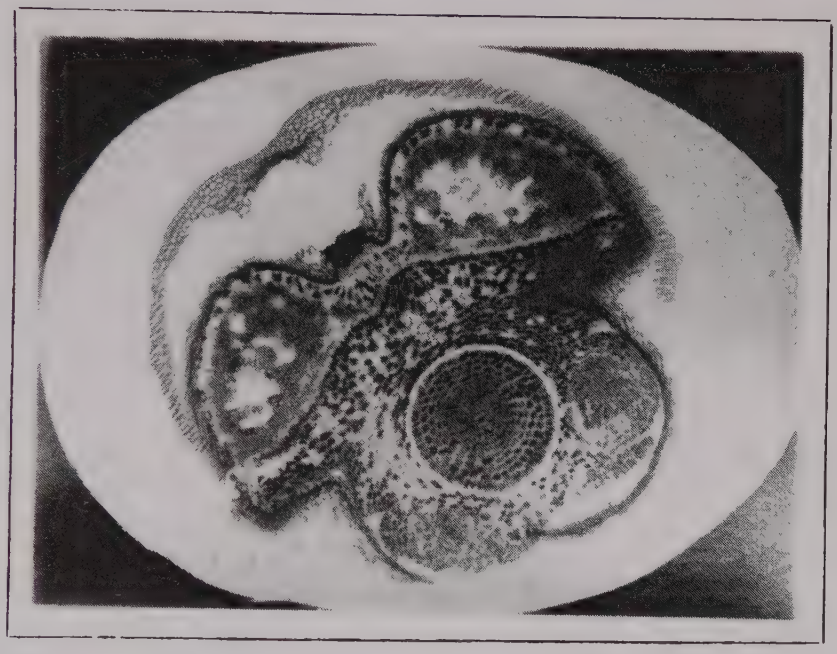
A Photo-Micrograph of a Cross-section through the Germ and Placenta.

Magnified 35 diameters.

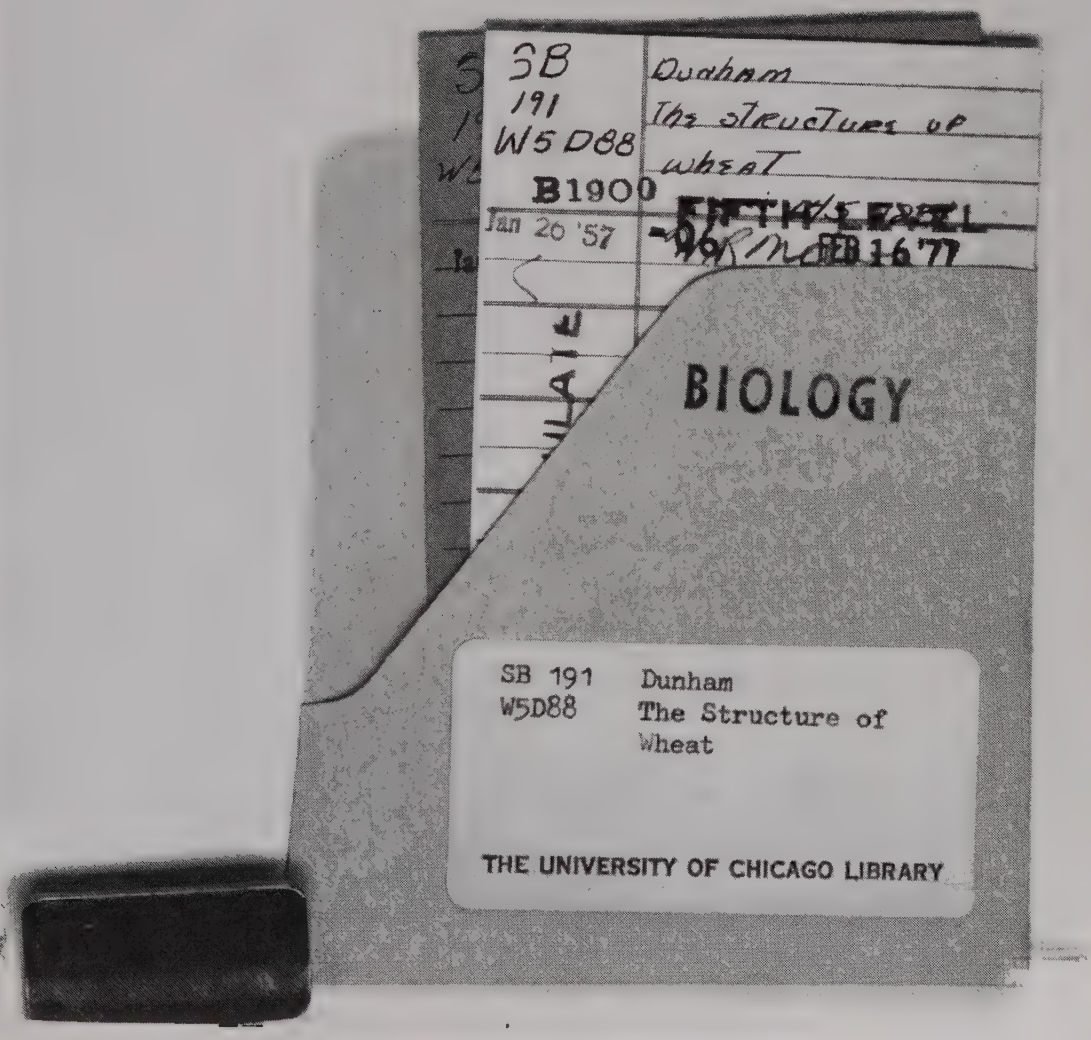
The placenta of the wheat berry enters the grain between the germ and the bottom of the crease, and as it enters the berry it branches in two. One of the branches serves to feed the embryo while the wheat is forming, and the other passes up to the top of the berry at the bottom of the crease between the skins. The photo-micrograph above is a cross-section of a grain of wheat through the germ, magnified 35 diameters, and shows the exact position of the placenta between the skins at the bottom of the crease. The dark portion at the base of the photo-micrograph is the germ, and it will be noticed that the three roots are well defined.

A Photo-Micrograph of a Cross-section at the extreme Germ End of Berry.

Magnified 50 diameters.



The above is a cross-section at the extreme end of the wheat berry, and shows the placenta and germ at a point where they nearly meet. The slice of wheat was so thin that the outer skin broke away from the placenta; but it may be called a fortunate accident, since it has rendered the illustration much more clear and instructive than would otherwise have been the case.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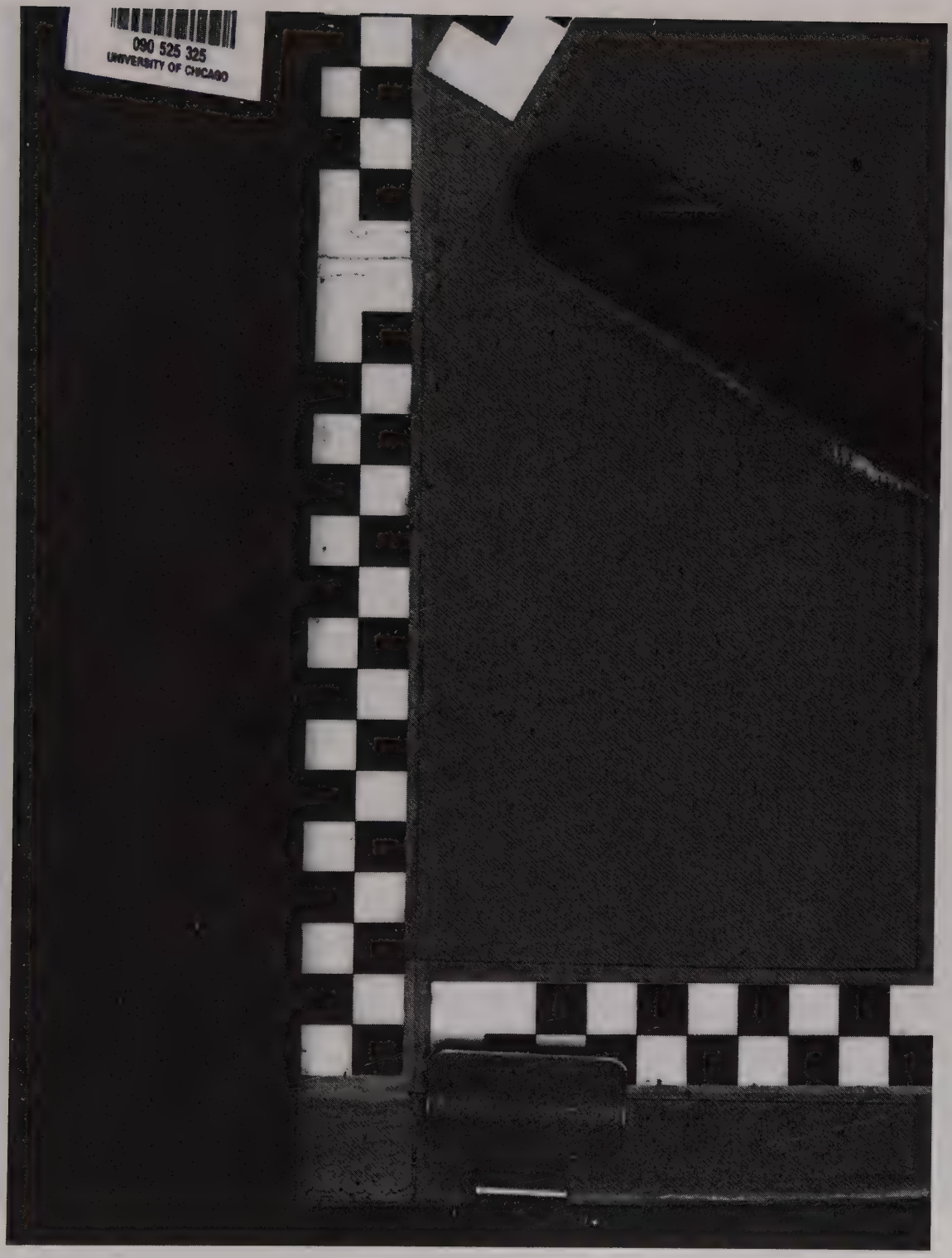

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